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LAND-SURFACE FLUXES AND HYDROLOGY WITH THE SIMPLE BIOSPHERE MODEL (SSiB) USING ANALYSIS OF OBSERVATIONS FROM ISLSCP INITIATIVE I

Y.C. Sud and David M. Mocko*

Laboratory for Atmospheres, Goddard Space Flight Center, Greenbelt, MD 20771

1. INTRODUCTION

Through our participation in the GEWEX land-model intercomparison project, we were able to utilize the ISLSCP CD-ROM data (Meeson *et al.*, 1995) to drive our version of the Simple Biosphere Model (SSiB) and simulate land surface fluxes and hydrologic fields for 1987–1988. This version of SSiB is being used in the 17-layer version of GLA/GOES GCM both of which are being used in the Climate and Radiation Branch. We have analyzed the SSiB simulation with the goal of isolating its strengths and weaknesses. Such investigations are vital for calibration/validation of submodels of a GCM. It is generally understood that hydrologic processes and biospheric fluxes strongly influence the lower troposphere and the moist processes emanating from the boundary layer (e.g., Sud *et al.*, 1995). Consequently, validation of land-process parameterizations in models deployed for understanding climate variability is vital. This paper should be read in conjunction with the Mocko et al. (Paper P7.4, this volume) paper in which the calculation procedures are better described along with a comparison of SSiB with one (three) well known simple land models schemes that have been used in GCMs and global energy and water balance studies. The following is a summary of our results.

2. REGIONAL TRANSECTS

We have examined the time evolution of land hydrology in several regions of the world. This is done by producing time-longitude transects. Fig. 1 shows two east-west transects: one over Amazonia at 10S and one over Sahel at 15N. These transects highlight the differences in the annual cycle of land processes in wet tropical and dry desert regions. In Amazonia, the precipitation field shows values over 6 mm/day during the local summer and less than 1 mm/day during the local winter; this is accompanied by a relatively uniform evapotranspiration throughout the period. Thus we see that the soil moisture storage maintains a reasonable water availability during the dry periods which is essential for maintaining a rainforest. The model seems to produce realistic evapotranspiration throughout the year. The precipitation minus evaporation transect also shows a strong annual cycle with highest runoff in April (not shown). Evidently, the prescribed root zone depth and soil moisture availability in the tropical forests (SSiB biome-1) helps to maintain evaporation in the dry periods. In the Sahel, the precipitation is seasonal and appears during the summer monsoon season. High evaporation continues for several months following the rainy period (when cloudiness reduces and copious sunshine hits land) yielding a strong annual cycle of this field. The P - E and runoff fields also show a highly variable behavior even during the rainy season which is characteristic of the region because of 5-day cycles of the easterly wave with some clear days in between.

3. SOIL MOISTURE VALIDATION

For the period of this investigation, soil moisture data was available for most of Russia and the state of Illinois in the United States. The simulated soil moisture is compared with the observed. Available soil moisture here is defined as the available water in mm in the soil column in the top 1 meter depth. It is calculated as the total water in the soil column minus the wilting level value (a property of the soil and vegetation). Typically, the wilting point value is about one-third of the total storage capacity of the soil; however, it can be calculated from the following equation if an estimate of the specific soil and vegetation properties is available:

*General Sciences Corporation, Laurel, MD

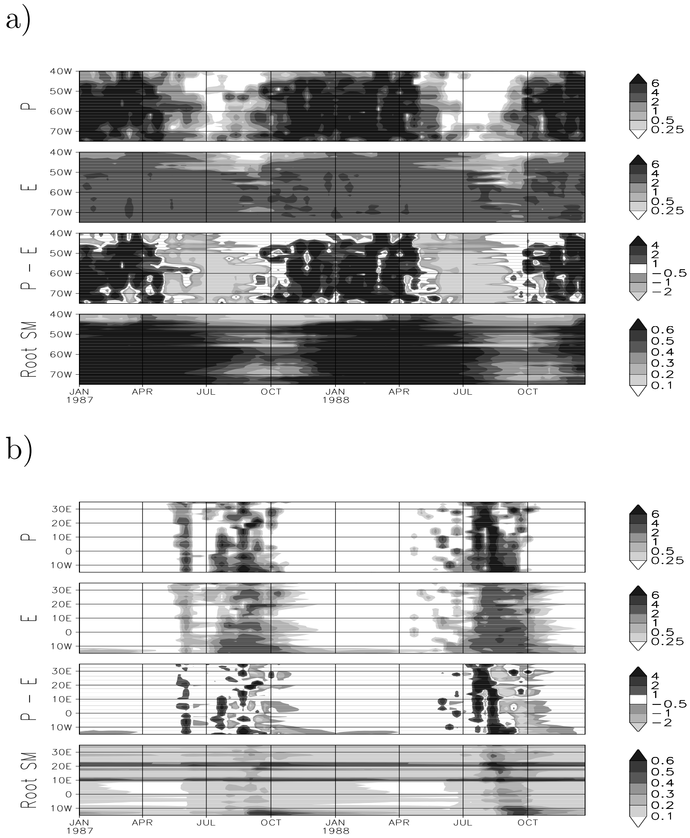

Figure 1: Time-longitude transects of precipitation (top), evaporation (second from top), precipitation - evaporation (third), and root zone soil wetness (bottom) from the SSiB model in: a) Amazonia along 10S; b) Sahel along 15N.

$$WP = n * D * (-exp(C_1)/\psi_s)^{-1/b}, \qquad (1)$$

where WP is the wilting point value of soil moisture in mm; n is the soil porosity; and D is the depth of soil (mm) which is 1 meter in the observation and must be obtained for the SSiB simulation in this comparison. C_1 is a biophysical parameter of the local biome/vegetation (m) from Xue *et al.* (1991) and ψ is the soil matric potential (ψ_s, at saturation) in m. The soil characteristics are provided in the data, where b relates ψ to ψ_s through soil moisture fraction, W, by:

$$\psi = \psi_s W^{-1/b}. \qquad (2)$$

Russian data is collected over agricultural fields during the growing period (April 10 to October 31). The fields carry winter and spring wheat crops. The data is based on 500 agrometeorological stations. Further details about the data can be found in Vinnikov and Yeserkepova (1991). We have averaged the soil moisture values for 55 to 65N and 20 to 60E. Figure 2a shows a comparison of the available soil moisture produced in the SSiB simulation and the observations. Observations are separately aggregated for winter and summer wheat crops. A systematic difference of about 50 mm can be noted between the simulated and observed values with some slightly larger differences in the early spring. Our examination has revealed that these differences are related to the differences in the inferred wilting value of the soil moisture in the observations and the model from Eqn. (1). The model calculates larger wilting values in the region; consequently, it produces lower available soil moisture values. We plan to run a case with readjusted wilting value of soil moisture in SSiB and evaluate the resultant improvement.

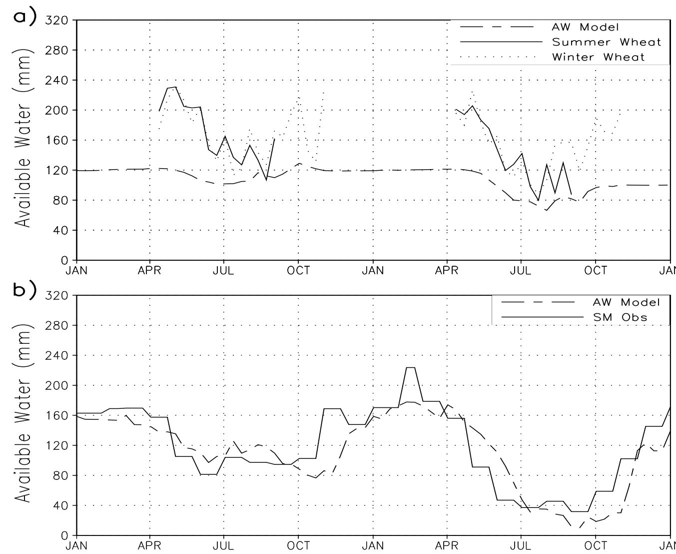

Figure 2: Model simulated (dashed) and measured (solid/dotted) available water in the top meter of soil for: a) Russia and; b) Illinois sites for the analysis period.

A second averaging region is within the state of Illinois, 38 to 42N and 88 to 90W, and is located in the north-central United States. This data set contains weekly data for the growing season and monthly data for the winter season. The region is almost entirely comprised of cultivated agricultural fields. For more detail on the dataset, the reader can refer to Hollinger and Isard (1994). We gridded the data using the Cressman (1959) objective analysis technique available in GrADS. Figure 2b shows the model simulated versus measured values of available soil moisture agree quite well except for a slight lag in the minimum available soil moisture at the end of the summer. In this case the wilting soil moisture values are also in close agreements with estimates of the observed. Similar biases and agreements were noted in the 10 year time series produced in the AMIP simulation with the GLA GCM model which used SSiB (not shown).

4. ANNUAL HARMONICS

We have examined the annual harmonics of surface fluxes of heat and moisture (Fig. 3a) as well as precipitation and runoff (Fig. 3b) for the entire period. It shows some well-expected differences between various climatic regions; e.g., no runoff and virtually little evapotranspiration over the Sahara desert, large runoff over the Amazon and Congo basins, and very realistic phase relationships between sensible and latent heat fluxes and between runoff and precipitation over the Mississippi basin. In this way, we further infer that the model is doing a reasonable job of simulating the annual cycle of the surface fluxes and surface hydrology. Also evident in Fig. 3a are the phase relationships between sensible and latent fluxes at different latitudes. At subtropical latitudes, solar heating of dry land precedes the formation of monsoon circulation that brings rains recharging the soil water to boost evapotranspiration in succeeding periods. Near the equator, the Sun has two annual passes; consequently, there is no clear annual cycle. Indeed, this shows in the magnitude and phase relationship of heat and moisture fluxes as well. These relationships change at high latitudes; particularly, in the northern hemisphere, the late spring/summer snowmelt generates large runoff while snowfall in winter generates virtually no runoff. The long seasonal time-scale persistence of this feature is responsible for the high amplitude of the annual cycle of runoff. Evidently, it exceeds even the amplitude of the annual cycle of precipitation. One can get a good insight into the behavior of annual cycle of river flow by examining the behavior of the annual cycle of runoff (not shown) vis-a-vis the amplitude of the annual cycle of precipitation. This figure depicts the key features of the annual cycle. Extensive details of hydrologic features will be presented at the meeting.

5. CONCLUSIONS

Calibration and validation of the hydrologic processes over land are fundamentally vital to modeling studies for assessing the influence of land atmosphere interactions on the observed as well as anticipated climate change. It is well known that the issue of the influence of tropical deforestation on the local and global climate remains largely illusive, even though it has caused considerable international anxiety (Henderson-Sellers *et al.*, 1993; Sud *et al.*, 1996). The only tools that can address such issues are earth-atmosphere system models and the realism of the physical parameterizations in these models require extensive calibration and validation efforts. This paper focuses on validation of land-hydrology parameterization but the process has to extended to other parameterizations as well. We were indeed encouraged to find that the several gross features of the SSiB hydrology have turned out to be realistic (suggesting that its influence in a GCM simulation is likely to be reasonable). Nevertheless, we also found some problems with the detailed spatio-temporal structures of the hydrologic cycle, river flow in the river routing network recently developed by Oki et al. (in preparation) following Miller *et al.* (1994). Some of the outstanding issues that require attention and the influence of adjusted wilting soil moisture values on the available soil moisture will be addressed in the future.

6. ACKNOWLEDGMENTS

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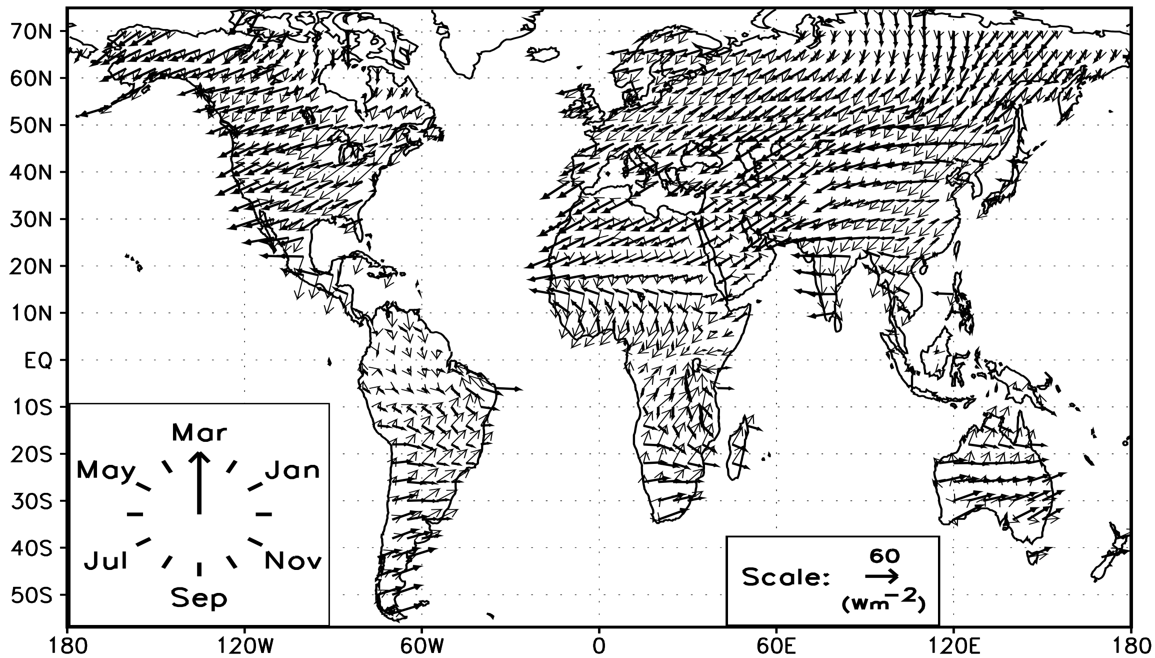
a)



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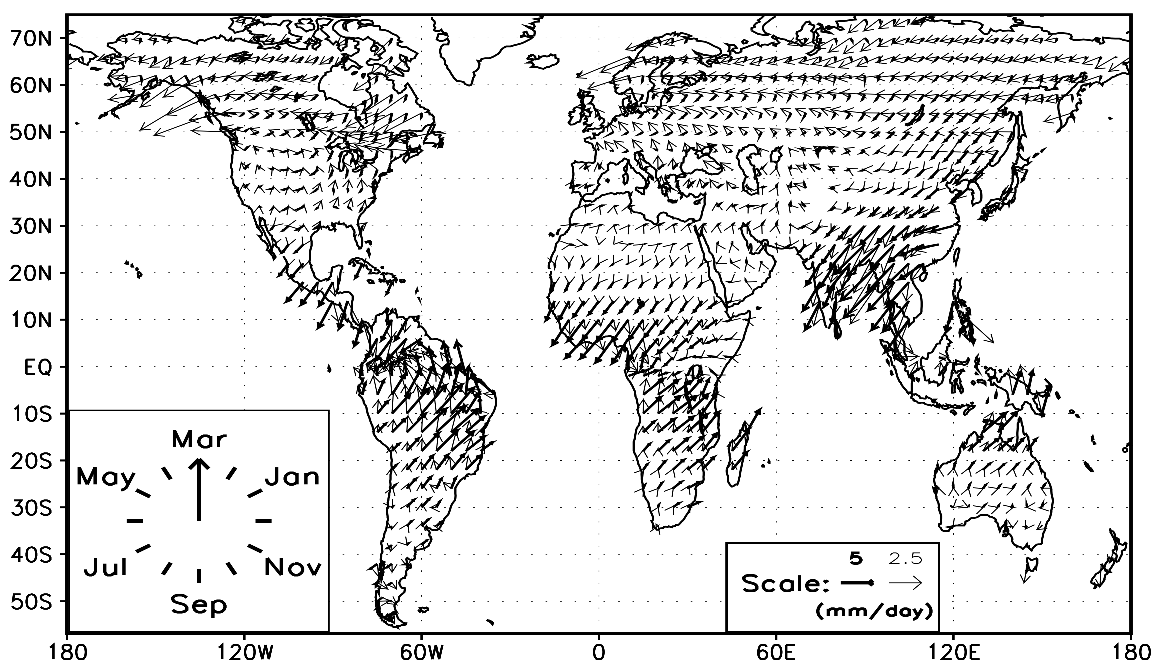

Figure 3: Annual harmonic of: (a) surface fluxes of heat (thick) and moisture (thin) and; (b) precipitation (thick) and runoff (thin). The vector scale and the time phase are included in the figures.